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ABSTRACT

Performance data for 42 subjects pertaining to seven course objectives and ten propositional logic tasks were analyzed for hierarchical relationships using ordering theoretic technique. The resulting hierarchy indicated that simple implication and particular contraposition propositional logic tasks were prerequisite to some course objectives. This procedure was discussed as being useful in generating hierarchies in subject areas less amenable to this process and of value in the design and implementation of competency based teacher education and mastery learning systems. (Author)

Using Ordering Theoretic Technique to Analyze Hierarchical Relationships Among Intellectual Skills and Propositional Logic Tasks

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Gagné's work pertaining to learning hierarchies (1968) and types of learning (1970) has provided educators with a valuable method for determining the necessary prerequisites for predetermined outcomes (objectives). Research has indicated rather strong support for the use of hierarchies in the math and science subject areas (White, 1973). However, there has been little work done in developing hierarchies in other subject areas where the content may not be so tightly organized as in math or science. White and Gagné (1974) suggest that subtle and complex hierarchies leading to principles, may exist in such subject areas but at present are difficult to identify.

This difficulty in generating such hierarchies has a definite effect on the design, development and implementation of competency-based and/or mastery learning type systems.

In general it has been our experience in the Competency Based Teacher Education Program at The University of Toledo that mastery learning techniques work fairly well for objectives which can be tested by objective means (e.g. multiple choice format). In such situations very specific feedback can be provided to students about their performance and recommended corrective (recycling) procedures can also be rather straightforward. If the objective pertains to a concept, the student could be provided with additional examples and non examples; while if the objective reflects primarily verbal information the student could be directed to reread the relevant sources or read some alternative sources. If these lower level objectives and corresponding criterion items are carefully designed, the great majority of students in the program do reach mastery. This is consistent with mastery learning research (Block, 1974).

On the other hand the experience with objectives requiring analysis-synthesis level behavior (Bloom et al., 1956) or problem solving behavior (Gagné, 1970) is quite different. In such situations the student constructs a response (e.g. designs a plan to solve a behavior problem in the classroom) and the instructor uses a criterion checklist in evaluating the response. This checklist includes characteristics which need to be included in the student's response. The use of this checklist allows for more objectivity in evaluation. The instructor can then provide feedback to the student about his performance with respect to these characteristics. In many such situations the student is provided with such feedback and asked to make the necessary corrections so that the appropriate criterion level can be attained. In addition, the student might be asked to reread some important articles related to the improvements necessary in the paper and perhaps work with other students who have similar problems. The outcomes of such interactions seem to cluster in three categories:

(1) The student understands the feedback, participates in the corrective procedures, and improves the quality of the paper.

(2) The student understands only part of the feedback and as a result when attempting to make corrections in the paper includes at best a paraphrase of the instructor's comments and actually does not improve the quality of the paper.

(3) The student does not understand the feedback and clearly cannot improve the quality of the paper at that time.

It takes no major insight to conclude that students in categories

2 and 3 lack the necessary prerequisites to "master" the competency as desired. But just what are these prerequisites? Attempts at generating hierarchies for such competencies yield some important information but lack the specificity needed to write and sequence objectives. For example, the objective referred to above of solving behavioral problems in the classroom requires, no doubt, prerequisite rule governed behavior with regard to positive reinforcement, successive approximations, schedules of reinforcement, etc. However to what extent is such prerequisite knowledge necessary? Obviously more than recognition and recall skills are required. But how does one demonstrate these prerequisite rule governed behaviors? The answer gets even more complex when one considers the various conditions in which it would be desirable that the student could demonstrate such competence. It seems logical that such prerequisites could be stated but the analysis required may be too time consuming to be feasible at this time. In addition, some students can learn to perform the problem solving competency without formal assessment of their ability to perform these difficult to determine prerequisite skills. These factors plus the observation that the same students seem to have problems with all the higher problem solving type objectives encouraged us to explore the existence of more general prerequisite abilities.

Gagné (1970) refers to these general capabilities as cognitive strategies, and that the learner uses these in managing his own thinking behavior. Piaget's view (1950) is that such "strategies" develop in identifiable stages each representing more complex capabilities in logical operations. Furthermore, these stages as evidenced in logical operations would set limits to the kinds of intellectual skills which learners would be able to perform (Gagné & Briggs, 1974). Gagné's view (1970, pp. 289-301) is that these strategies develop out of the learning of specific intellectual skills by a process of generalization rather than simply maturing as the learner grows.

In any event detecting hierarchical relationships among general logical operations and specific intellectual skills may be valuable for the following reasons:

(1) In assessing required entry capabilities when specific intellectual skill hierarchy information is not available.

(2) As a possible aid in determining intellectual skill hierarchies in "difficult" content areas (e.g. finding that a particular logical operation is prerequisite to a specific objective of the problem solving type may facilitate the analysis required in determining the form which the specific prerequisite rule using objectives should take).

Recent work by Airasian, Bart and Greaney (1975), and Bart and Airasian (1974) has provided a framework in which to carry out such research. In both studies referred to above, the authors employed the ordering theory technique in generating hierarchies which depicted the prerequisite relationships among sets of Piaget tasks of logical propositions. In the Bart and Airasian study (1974) the resulting hierarchy confirmed Piaget's stage theory of concrete operations as being prerequisite to formal operations, but also found intra stage prerequisite relationships. In the Airasian, Bart and Greaney study (1975) an ordering theory analysis of a propositional logic game, which tested 16 binary propositions, yielded a complex hierarchy which the authors suggested could depict the pattern of intra-period formal operational development for the understanding of binary propositions.

Very briefly, ordering theory (Airasian & Bart, 1973) is a deterministic measurement model which uses individual task performance patterns to identify both linear and nonlinear prerequisite relationships among those tasks. A task "i" is considered prerequisite to task "j" if the (0, 1) disconfirmatory response pattern (where 0 represents incorrect performance on task "i", and 1 represents correct performance on task "j") does not occur, or occurs infrequently. Ordering theory can either be used to generate the most likely hierarchy among a set of tasks or verify an a priori hypothesized hierarchy among a set of tasks. This latter use of ordering theory differs from Gagné's method of hierarchy validation (Gagné, 1962) in that the relationships of all task pairs is examined and not just those hypothesized to have prerequisite relationships.

In summary, while hierarchical relationships have been analyzed among intellectual skills in a series of studies by Gagné and others (White & Gagné, 1974), and among logical reasoning tasks (Airasian, Bart & Greaney, 1975; Bart & Airasian, 1974), there are no studies with which this author is familiar that have explored hierarchical relationships among tasks which include both specific intellectual skills and logical reasoning capabilities.

This then is the purpose of this study and that is to use the ordering theoretic technique in exploring the hierarchical relationships among a set of tasks which include specific intellectual skills and logical reasoning capabilities.

Method

Subjects used in this study were 42 students enrolled in a course entitled, "Behavior Modification in the Classroom" for Winter Quarter, 1976. This number included 12 upper level undergraduates and 30 graduate students.

The tasks which were included in the ordering theory analysis included 7 objectives from the Behavior Modification course and 10 propositional logic tasks. Briefly, the objectives were:

A. Labeling deficiencies in goal statements.

B. Selecting the appropriate observation technique for a given behavior.

C. Judging an <u>intended</u> action as either positive reinforcement, negative reinforcement or punishment.

D. Judging an <u>effect</u> as either positive reinforcement, negative reinforcement or punishment.

E. Generating a goal statement for a case study.

F. Describing how to collect baseline data for the same case study.

G. Designing the behavior change plan for the same case study.

Objectives A thru D were multiple choice with a 90% criterion level (9 of 10). Objectives E thru G were evaluated with the use of criterion checklists with a minimum of 80% of the items marked "yes" needed to achieve the required criterion level.

With regard to the logic tasks, each student was presented with two logical propositions of the form:

If P then Q: if Q then R

For the first proposition the P represented 'kangaroo', Q represented 'marsupial', and R represented 'animal'; while in the second proposition P, Q, and R represented the nonsense words yuccapuck, gorkmeyer, and kablatza, respectively. The sample question and the ten formal questions asked for each proposition are depicted below for the second proposition. The same set of questions were asked for each proposition but in different random order.

Sample Question

If we know that P is a yuccapuck than what can we say about Q and R?

Correct Response

Q = ?--It is given that P is a yuccapuck so therefore Q is a gorkmeyer since in the original proposition it is stated 'if P then Q'.

R = ?--Since it was given that P is a yuccapuck and subsequently determined by implication that Q is a gorkmeyer then R is a kablatza since in the original proposition it is stated 'if Q then R'.

Please answer the following questions on this sheet of paper where indicated.

(a) $\overline{Q}$-It is <u>not</u> a gorkmeyer
P-?
R-?

(b) $\overline{R}$-It is <u>not</u> a kablatza
P-?
Q-?

(c) $\overline{P}$-It is <u>not</u> a yuccapuck
Q-?
R-?

(d) R-It is a kablatza
P-?
Q-?

(e) Q-It is a gorkmeyer
P-?
R-?

For a logic task to be scored as correct (e.g., if R what can be said about P?), both examples (one from each proposition) had to be answered correctly.

Results

Each subject had dichotomous scores ("0" or "1") for each of the 7 objectives and 10 propositional logic tasks. A computer program (Lele & Bart, 1971) was used for the ordering theoretic hierarchical analysis. Since ordering theory is a deterministic model and not probabilistic, it does not have a method of dealing with random error in task response patterns. As a consequence, this analysis relies upon a preset tolerance level which sets a limit on the number of (0 1) or disconfirmatory response patterns allowable before necessitating the rejection of a prerequisite relationship. In this study a 5% tolerance level was used which meant that a maximum of 2 disconfirmatory response patterns was allowable.

The resulting hierarchical relationships are presented in Figure 1. Only those tasks having such relationships are presented. The remaining

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Insert Figure 1 about here

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eight tasks, if depicted graphically, would be standing alone with no connecting arrows. However the point should be made that with a higher tolerance level of 10% many more hierarchical relationships would be evident.

Three kinds of prerequisite relationships exist in the hierarchy; (1) between course objectives (objective B prerequisite to objective G), (2) between logic tasks ('if Q what can be said about R', as prerequisite to 'if Q what can be said about P')., and (3) between a logic task and a course objective ('if $\overline{R}$ what can be said about Q', as prerequisite to objective G).

Discussion

The purpose of this study was to investigate the hierarchical relationships among specific intellectual skills and propositional logic tasks. Two such relationships were found. The task 'if Q what can be said about R', while found to be prerequisite to both objectives D and G, constitutes only a simple affirmation of the given implication form, 'if Q then R'. As such it provides only the most basic information about the necessary logical reasoning capability which is necessary in performing objectives D and G. The other prerequisite relationship between a logic task and a course objective, i.e., 'if $\overline{R}$ what can be said about Q', being prerequisite to objective G, is perhaps of more value. In formal logic this task is called particular contraposition and represents a more sophisticated level in logic (Ennis, 1975).

Objective G is most appropriately labeled as problem solving with respect to Gagné's types of learning (1970). The objective involves designing a solution, using behavioral techniques, for a classroom behavior problem. In doing so students would be using rules (principles) pertaining to positive reinforcement, shaping, schedules of reinforcement, etc.

Applying these rules would involve hypothetico-deductive reasoning in that the student would have to figure out logically what would be likely to occur if one or more of these rules were to be applied to the specific problem stated (Flavell, 1977). The following example may represent the nature of contraposition logic required in solving the problem:

> If the behavior is discrete and easily countable than a ratio reinforcement schedule would be appropriate. . . However what would I know about the behavior if a ratio reinforcement schedule was not used?

While the results indicate that students who could not perform logic tasks of the form 'if not R what can be said about Q', did not succeed on the problem solving objective G, there is no clear direction to follow in helping students acquire these forms of logic. When using intellectual skills hierarchies, instruction can begin at that point in the hierarchy in which the student first experiences difficulty. In this case some elements in the hierarchy pertain to general reasoning capabilities which take more time to acquire (or develop) regardless of whether it is viewed from a Gagné or Piaget framework. In addition, one certainly cannot make the assumption that training in propositional logic alone would lend positive transfer to the specific intellectual skills in question.

Future research along these lines should at least include the following:

(1) Additional hierarchical studies to determine if there are consistent hierarchical relationships between specific propositional logic capabilities and specific intellectual skills (in many different content areas).

(2) 'Protocol' analyses of the performance of specific intellectual skills in order to determine the use of propositional logic during the process. Such analyses may be helpful in (a) designing specific prerequisite intellectual skills and/or (b) providing guidelines for the design of possible enrichment/intervention materials which may provide learning experiences which facilitate the attainment of the problem solving capability.

Finally, there is a more pragmatic and ethical concern which has arisen from such research. The outcomes oriented approach of CBTE and mastery learning necessitates the development of measurement techniques which assess the attainment of the specific objectives. The more valid and reliable the measurement instruments the more confident we are in making decisions based on their use. If we can measure the terminal objective of a course and subsequently determine a prerequisite propositional logic capability we have the ability to predict in advance those students who will not be able to perform well in that course. What will we do with such information? Counsel the person out of the course? Ignore the data and assume that the problem is the student's responsibility? Provide for individualized instruction?

To be sure, the answers to these questions have far reaching consequences. However, it is most important to be honest with ourselves. Is it possible to implement these programs and not address ourselves seriously to the entry capabilities of students? Can we be comfortable with the knowledge that some students in our course will not succeed no matter how responsible they behave in attempting to complete the coursework? This matter needs our immediate attention since the better we get at designing and implementing such innovative programs the more clear will be the discrepancy between the expected outcomes and the present capabilities of a good number of our students.

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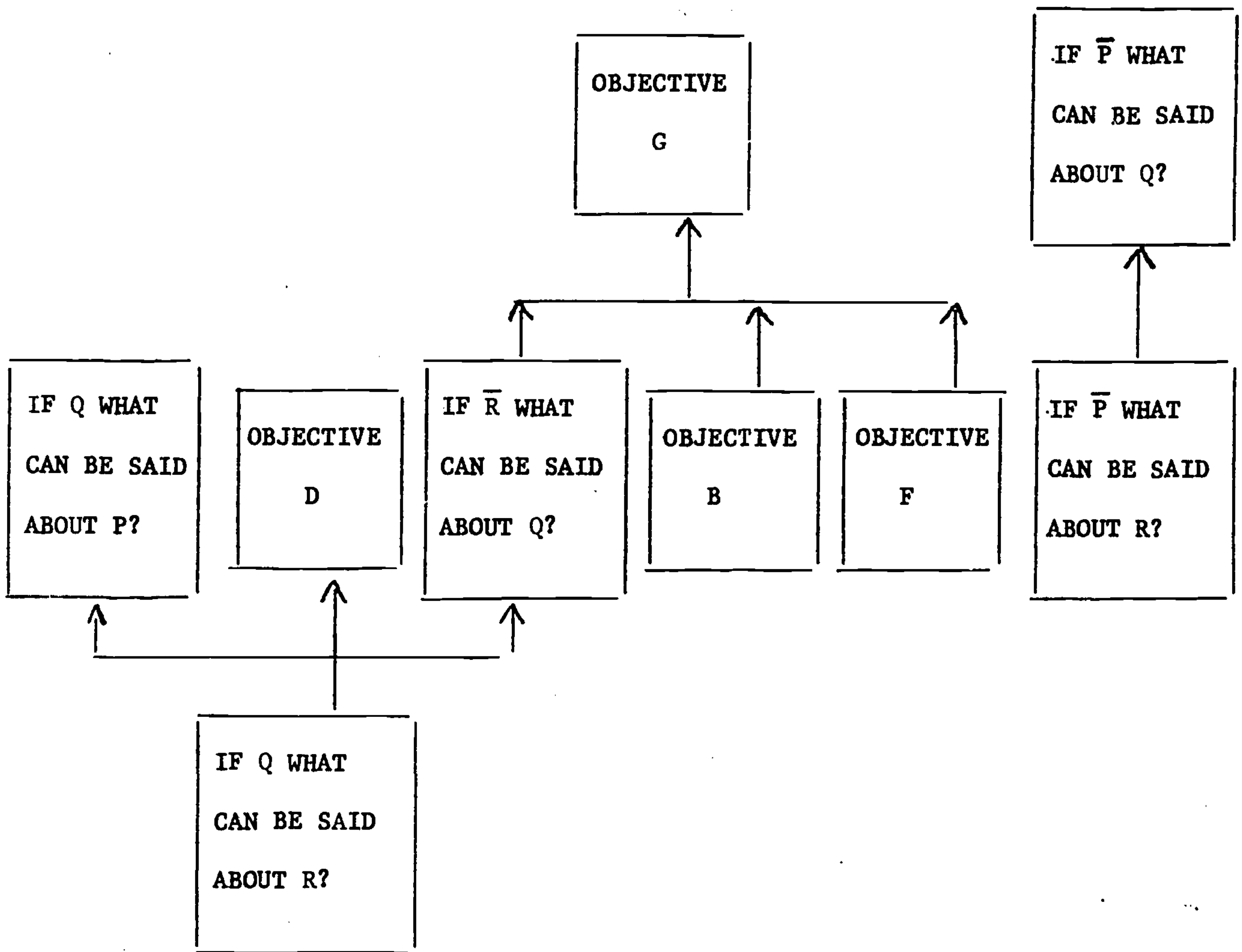

Figure 1. The hierarchical relationships among intellectual skills and propositional logic tasks.